Groundwater test pumping in the Tambellup townsite

Louise Hopgood

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GROUNDWATER TEST PUMPING IN THE TAMBELLUP TOWNSITE

Louise Hopgood

December 2003
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Disclaimer

The contents of this report were based on the best available information at the time of publication. It is based in part on various assumptions and predictions. Conditions may change over time and conclusions should be interpreted in the light of the latest information available.

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Summary

Long-term test pumping of a production bore in Tambellup took place for 20 days in March and April 2001. Data generated by the test pumping was analysed along with groundwater monitoring, climate and geological data.

Analysis indicated that a perched aquifer may be present in parts of Tambellup but that deeper aquifers formed by alluvial sand and saprolite and containing saline groundwater constitute the most extensive aquifers below the town.

A regional watertable of 1.0 to 2.5 m below ground level (bgl) during winter was identified which is likely to be causing damage to infrastructure in parts of town. This watertable responded to a pumping rate of 60 m$^3$/day, with likely drawdown after six months of pumping of 0.3 m up to 430 m from the production bore and 0.8 m up to 30 m from the bore. Additional production bores spaced about 500 m apart may be required to drawdown the watertable by 0.8 m across the entire town.

A potentiometric surface formed by the saprolite aquifer was identified which lies between 2.2 and 2.8 m bgl at most sites during winter and is unlikely to be directly impacting on infrastructure. The potentiometric surface responded to pumping and this will aid in drawdown of the watertable.

Test pumping has not proven if the possible perched aquifer responds to pumping.

Extrapolation of the test data suggests that pumping the existing production bore may provide benefit over a substantial section of Tambellup and it is recommended that the production bore be equipped with a pump and pumped initially at a discharge rate of 60 m$^3$/day.

To determine if the shallow aquifer identified in Tambellup is perched and if pumping has influence on the potentially perched aquifer, six shallow bores should be drilled within 100 m of the production bore and water levels in them monitored weekly once pumping begins. If pumping does not affect the perched watertable then upgrading of surface drainage may be required in specific areas.

Depending on the performance of the existing production bore, there may be a requirement for three additional production bores. If required, it is suggested that drilling and commissioning of further production bores be staged over several years so individual assessment of each new stage can be conducted, and the overall design changed accordingly for maximum impact.

The Tambellup production bore screens multiple aquifers and this makes determination of parameters for individual aquifers difficult. Production bores should be constructed to target only one aquifer or have the ability to isolate aquifers through packers to enable a more rigorous analysis of test pumping data.
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1. Introduction and background

Tambellup is located approximately 275 km south-east of Perth (Figure 1-1). Buildings and roads in the town have been subject to deterioration and trees have died due to saline groundwater that lies close to the soil surface (Ferdowsian and Ryder 1998).

Several drilling programs have taken place in Tambellup since 1985 during which monitoring bores and a production bore were constructed as part of efforts to monitor and manage groundwater issues in the town (see Figure 1-2).

The Department of Agriculture carried out a study of the groundwater salinity and surface and groundwater hydrology of Tambellup town and the surrounding Jam Creek catchment (Ferdowsian and Ryder 1998). This concluded that Tambellup was underlain by a perched aquifer containing fresh to brackish groundwater (mostly 240 to 1,000 ppm, although one measurement in salt-affected land was 2,250 ppm) and a deeper aquifer containing saline groundwater (6,000 to 18,600 ppm).

The study also indicated that downward groundwater gradients existed that might allow groundwater from the perched aquifer to recharge an underlying deep aquifer. The main recommendation was upgrading surface water drainage systems in the town to limit recharge to the deep aquifer beneath the town.

A groundwater study of Tambellup town was subsequently carried out by the Department of Agriculture in 2000. Details of the study were provided by Whitfield (2001). The study included drilling and construction of production bore 00TAMPB1 and 23 monitoring bores, followed by test pumping of the production bore over three days and then groundwater flow modelling.

Results of the 2000 drilling and testing program indicated heavy clay likely to be part of the Pallinup Siltstone Formation provided a base to the perched aquifer and semi-confined the deeper aquifer. Recharge to the deeper aquifer from the perched aquifer was predicted to be low. Test pumping and groundwater modelling indicated that groundwater pumping may be an effective way of protecting townsite infrastructure by lowering the watertable beneath the town. Longer-term test pumping was recommended to further investigate this option.

Longer-term test pumping of the production bore was undertaken for 20 days in March and April 2001. The testing program was supervised by the Department of Agriculture. In 2003, Global Groundwater was engaged to analyse data from the test, to provide recommendations for long-term operation of production bore 00TAMPB1 and to comment on potential of long-term pumping to lower the watertable. This report presents results of the test pumping and provides likely bore yields, prediction of pumping influence and likely optimum production bore spacing.
Figure 1-1: Location of Tambellup townsite.
2. Program description and methodology

2.1 Drilling and bore construction

Production bore 00TAMPB1 was drilled in 2000 behind the Shire Office using the mud rotary method. It was constructed to about 28 m bgl (below ground level) with 125 mm Class 12 blank and slotted PVC casing. The casing slot apertures were 1 mm and the slots extended from approximately 1 to 28 m bgl, thus the bore was effectively fully slotted. This made analysis of individual aquifers difficult and jeopardised the predictive power of the aquifer test. Other bores monitored during test pumping were drilled in 1997 and 2000 and constructed with 40 or 50 mm Class 12 PVC casing with 2 to 2.5 m slotted sections at the base of each bore.

The 1997 and 2000 drilling programs were supervised by the Department of Agriculture and available details are given by Ferdowsian and Ryder (1998) and Whitfield (2001).

2.2 Groundwater monitoring

Department of Agriculture monitors groundwater levels and electrical conductivity of groundwater in bores at Tambellup, mostly at three monthly intervals. Groundwater monitoring data from June 2000 to May 2003 were provided to Global Groundwater for the test pumping analysis. Data were used to correct test pumping drawdown measurements so that where possible, natural groundwater trends unrelated to pumping could be separated from groundwater response to pumping.

Longer-term monitoring data were also used to estimate likely winter watertable rises for inclusion in predictions of watertable response to long-term pumping. Recommendations for dewatering subsequently used highest seasonal water levels measured over the last three years as a base.

Water level and electrical conductivity monitored at each site during test pumping were also analysed to assist interpretation of which bores were constructed in the perched aquifer.

2.3 Climate

Daily rainfall records for Tambellup obtained from the Bureau of Meteorology from January 2000 to June 2003 showed that only 1 mm of rain fell during test pumping and consequently drawdown data were not corrected for rainfall.

Average daily barometric pressure records were not available for Tambellup but were obtained for Katanning, the closest available station. Pressure data were plotted against test pumping data to determine if variations in drawdown were due to variations in barometric pressure.
2.4 Test pumping

Test pumping of production bore 00TAMPB1 commenced on 29 March 2001, continued over 20 days and was supervised by the Department of Agriculture. A discharge rate of 78 m³/day was set for the bore. Information was not available on how the discharge rate was regulated and the accuracy of measurement. The discharge rate was selected on the basis of a step-test and 3-day constant-rate test carried out in September 2000 (Test Pumping Australia 2000).

Water levels were measured during the pumping and recovery phase of the 20-day test in the production bore and 13 monitoring bores at six sites located between 15 and 567 m from the production bore (Figure 1-1). The measurement method and its level of accuracy are unknown.

Test pumping data were provided to Global Groundwater and were analysed using standard techniques. Distances between monitoring and production bores were provided by the Department of Agriculture. Estimated position error was unknown.
3. Aquifers

The geology at Tambellup was described by Whitfield (2001) and the interpretation of aquifers here was based largely on that work.

Tambellup is underlain by Archaean granitic basement rocks of the Yilgarn Craton. The basement rocks are deeply weathered with eluvium (products of \textit{in situ} weathering) consisting of saprolite, clay and silt with minor sand extending from the fresh basement rocks to the surface. In places, later stream activity had eroded the eluvium and deposited alluvium of the Pallinup Siltstone Formation (Whitfield 2001). Deposits of aeolian sand were also present overlying the eluvium and alluvium. Whitfield indicated that the total thickness of eluvial, alluvial and aeolian deposits above the fresh basement rocks intersected by drilling was between 23 and 32 m.

Sandier, more permeable sections of the strata above the basement rocks form aquifers. The more clayey and silty, or less permeable sections of strata form aquitards. Several aquifers were identified on the basis of previous work (Ferdowsian and Ryder 1998, Whitfield 2001).

A perched aquifer containing fresh to brackish groundwater was interpreted to be present but deeper aquifers containing more saline groundwater and formed by alluvial sand and saprolite formed the most extensive aquifers beneath Tambellup. The distribution of the strata was highly variable and it was difficult to delineate accurately the occurrence of the aquifers and aquitards over large distances.

Correspondingly, for the purpose of test pumping analysis, bores were arbitrarily determined to be screened at deep, intermediate or shallow depths. Production bore 00TAMPB1 was interpreted to be constructed against the alluvial sand aquifer and deeper saprolite aquifer.

Four deep monitoring bores were constructed to depths greater than 20 m bgl and slotted against varying strata. Monitoring bore 00TAM18I was slotted against alluvial sandy clay and bore 00TAM05I against \textit{in situ} eluvium (pallid zone clay). The remaining two deep monitoring bores, 00TAM21D and 00TAM12D, were slotted against the saprolite aquifer.

Four intermediate depth monitoring bores, 00TAM21I, T5D/97, 00TAM13I and T12D/97, were constructed to depths between 8 and 12 m bgl. These bores were slotted against the alluvial sand aquifer.

Five shallow monitoring bores, 00TAM21M, T5S/97, 00TAM14M, 00TAM13M and 00TAM18M, were constructed to depths of less than 6 m bgl. These bores were slotted against alluvial sandy clay.
4. Test pumping results

4.1 Constant-rate test

4.1.1 Production bore 00TAMPB1

Bore 00TAMPB1 was pumped at a discharge rate of 78 m$^3$/day during the 20-day constant-rate test. Data for the tests are presented as a plot of drawdown versus time in Figure 4-1.

Rapid drawdown occurred during the first minute and was largely attributed to well losses. The shape of the early part of the drawdown curve suggests casing storage may have affected drawdown in the bore for up to about 20 minutes. The rate of drawdown was then effectively stable until 90 minutes into the test when the discharge rate dropped to 57 m$^3$/day causing a sudden recovery in the water level. The discharge rate then returned to 78 m$^3$/day and the rate of drawdown had stabilised by 180 minutes. Information is not available to explain the sudden decrease in discharge rate.

The rate of drawdown was effectively stable between three and 20 hours of pumping after which it increased slightly. This suggests that the cone of depression may have intersected a barrier or boundary.

The drawdown rate then remained relatively stable until the end of the test at 20 days. Minor variations in the established drawdown trend between 20 hours and 20 days are interpreted to be diurnal variations in pump rate and barometric pressure. However, two relatively large departures from the established drawdown trend occurred after 19,200 and 27,540 minutes (13 days 8 hours and 19 days 3 hours) of pumping when the water level was at about 18 and 20 m bgl, respectively. In both instances, water level dropped quite suddenly by about 0.6 to 0.7 m. It is not clear from available data if these rapid water level falls were due to aquifer properties, variations in discharge rate, measurement errors, or other environmental factors unrelated to pumping.

The shape of the drawdown curve suggests a confined aquifer. Jacob’s straight-line analysis (Cooper and Jacob 1946) was conducted on the section of the curve between 20 hours and the end of the test. The slope of the drawdown curve indicated transmissivity of the aquifer was 4 m$^2$/day. Therefore, average hydraulic conductivity over the 27 m slotted section of the bore was approximately 0.2 m/day. If it was assumed that clay-dominated sections of the strata are effectively impermeable and contributed little water to the bore, then average hydraulic conductivity over the remaining permeable strata (4 m alluvial sand aquifer and 2 m saprolite aquifer) is approximately 0.7 m/day.

Analysis of data using the method of Papadopulos and Cooper (1967) indicated that storage in the casing affected drawdown data for about 40 minutes of the test. This corresponds with the appearance of the drawdown curve and validates the section of the curve used to calculate aquifer transmissivity and hydraulic conductivity. Details of the analysis are given in the Appendix.
Figure 4-1: Constant rate test results for production bore 00TAMPB1.
4.1.2 Deep monitoring bores

Constant-rate test data for deep monitoring bores are presented as a plot of drawdown versus time in Figure 4-2. Monitoring bore drawdown data were not available until 23 hours after pumping began. Drawdown was greatest close to the production bore and decreased with increasing distance away from the production bore. The monitoring bore drawdown curves are similar to those expected for confined aquifers.

Bore 00TAM21D, 15 m from the production bore, responded quickly to pumping, with drawdown of 3.44 m after 23 hours pumping. The rate of drawdown remained relatively constant from 23 hours to the end of the test. Total drawdown at the end was 5.77 m.

The response in bores 00TAM18I and 00TAM05I, 262 m north-east and 252 m south-west, respectively, from the production bore was less than for 00TAM21D showing significant response (0.135 and 0.235 m, respectively) after 48 hours of pumping. The rate of drawdown in these bores increased after four days and then remained effectively constant until the end of the test. Although both bores are at similar distances from the production bore, the response in bore 00TAM18I was greater than in 00TAM05I. Drawdown at the end of the test was 1.97 m in bore 00TAM18I and 0.80 m in bore 00TAM05I. This suggests different horizontal hydraulic conductivity in each direction.

Bore 00TAM12D, 567 m from the production bore did not respond until seven days and six hours of pumping after which the rate of drawdown remained relatively constant. Drawdown at the end of the test was 0.22 m.

Jacob’s straight-line analysis (Cooper and Jacob 1946) was conducted on the late section of each of the drawdown curves and results are given in Table 4-1. Transmissivity ranged from 7 to 34 m²/day and storage coefficient was 8.5 x 10⁻⁴. Average hydraulic conductivity over the 3 to 12 m aquifer thickness in bores indicates hydraulic conductivities of 1.3 to 3.8 m/day.

A distance-drawdown analysis was also performed on the data (Figure 4-3). Using the line of best fit, aquifer transmissivity was 8 m²/day; hydraulic conductivity was 1.3 m/day; and storage coefficient 8.7 x 10⁻⁴ (Table 4-1).

4.1.3 Intermediate monitoring bores

Constant-rate test data for intermediate monitoring bores are presented as a plot of drawdown versus time in Figure 4-4. Drawdown in the intermediate bores was less than that recorded in deep bores, but as for the deep bores, drawdown was greatest close to the production bore and decreased with increasing distance from the production bore. Minor variations in water levels are apparent and these are mostly consistent with diurnal variations noted in the production bore water levels. Other small variations may be due to measurement errors.

Bore 00TAM21I, 15 m from the production bore responded quickly to pumping, with drawdown of 0.84 m after 23 hours. The drawdown rate then remained relatively constant until the test end; final drawdown was 1.04 m.
Figure 4-2: Constant rate test results from deep monitoring bores.

Discharge rate (Q) = 78 m³/day
Static Waterlevel (hg)
00TAM12D = 1.78 m
00TAM05I = 1.80 m
00TAM18I = 3.34 m
00TAM21D = 3.00 m
Distance Drawdown - Deep Monitoring Bores

Figure 4.3: Distance drawdown of deep monitoring bores.
Figure 4.4: Constant rate test results for intermediate monitoring bores.
Figure 4-5: Distance drawdown for intermediate monitoring bores.
Bore T5D/97, 252 m from the production bore showed a small response with drawdown of 0.05 m after 23 hours pumping. The rate of drawdown increased after four days of pumping and was then effectively constant until the end of pumping when drawdown was 0.45 m.

Bore 00TAM13I, 355 m from the production bore showed minimal response to pumping until 8 days and 3 hours of pumping. Drawdown at the end was 0.24 m.

A small response to pumping of 0.04 m may have occurred in bore T12D/97 located 567 m from the production bore. However, diurnal variations apparent in the bore water levels are of a greater magnitude than the potential total drawdown in the bore and thus it is not clear that the changes in water level were drawndown in response to pumping.

Jacob’s straight-line analysis (Cooper and Jacob 1946) was conducted on the late section of each drawdown curve and results are shown in Table 4-1. Transmissivity ranged from 39 to 123 m²/day and storage coefficient was $4.0 \times 10^{-8}$. Average hydraulic conductivity over the 1 to 6 m thick aquifer indicated hydraulic conductivities of 8 to 31 m/day.

A distance-drawdown analysis performed on the data is shown in Figure 4-5. Bore data approximate a straight line. Using the line of best fit, aquifer transmissivity was 48 m²/day, hydraulic conductivity was 12 m/day and storage coefficient $2.5 \times 10^{-3}$ (Table 4-1).

4.1.4 Shallow monitoring bores

Constant-rate test data for shallow bores are presented in Figure 4-6. The shallow bores were less responsive to pumping than intermediate and deep bores and drawdown decreased with increasing distance from the production bore. The data also show diurnal variations in water levels consistent with those of the production bore. Other small variations may be due to minor measurement errors.

Bore 00TAM21M, located 15 m from the production bore, had the greatest response to pumping with 0.33 m drawdown after 23 hours. The rate of drawdown increased after four days of pumping and remained relatively constant until the end of the test with a final drawdown of 0.92 m.

Bore T5S/97, 252 m from the production bore, was 2 m deep and interpreted to be constructed in a perched aquifer. Long-term water level monitoring (Figure 4-7) shows the water level in the bore behaves erratically compared to long-term data from other bores. The data density is not sufficient to be conclusive but the water level may respond rapidly to rainfall (for example during 2001) possibly from rapid infiltration of surface run-off at the site or in the nearby Gordon River. Consequently, while monitoring during test pumping suggests water levels declined throughout the test, it is not conclusive if this was due to pumping or a natural decline.

Drawdown of less than 0.15 m as a result of pumping may have occurred in bores 00TAM14M and 00TAM13M located 196 and 355 m from the production bore. However, diurnal variations apparent in the bore water levels are of a greater
Figure 4.6: Constant rate test results for shallow monitoring bores.

Constant Rate Test
Shallow Monitoring Bores

Discharge rate (Q) = 78 m³/day
Static Waterlevel (bgf)
00TAM18M = 1.60 m
00TAM13M = 3.20 m
00TAM14M = 2.47 m
TSS/67 = 6.95 m
00TAM21M = 2.35 m
Figure 4-7: Long-term water level monitoring in shallow bores.
Figure 4-8: Distance drawdown from shallow monitoring bores.
magnitude than the potential total drawdown in the bores and thus it is not clear that
the changes in water level were drawdown in response to pumping.

Bore 00TAM18M, located 262 m from the production bore is interpreted to be
constructed in a perched aquifer. The water level in the bore showed no response
that could be attributed to pumping.

Jacob’s straight-line analysis (Cooper and Jacob 1946) was conducted on the late
section of each drawdown curve. Transmissivity ranged from 39 to 115 m²/day and
storage coefficient was 0.024. Average hydraulic conductivity over the 1.5 to 2.5 m
aquifer thickness indicated hydraulic conductivities of 16 to 58 m/day (Table 4-1).

A distance-drawdown analysis performed on the data is shown in Figure 4-8.
Excluding those bores in which water levels could not conclusively be considered to
have responded to pumping, bore data approximate a straight line. Using the line of
best fit, aquifer transmissivity was 46 m²/day, hydraulic conductivity was 23 m/day
and storage coefficient was 0.01 (Table 4-1).

4.2 Recovery test

4.2.1 Production bore 00TAMPB1

Recovery was monitored for 24 hours after cessation of pumping. Recovery data are
given as a plot of residual drawdown versus the ratio of t/t’ in Figure 4-9.

Slope of the residual drawdown curve from t/t’ 20.92 to 205.86 indicates aquifer
transmissivity of 10 m²/day and therefore average hydraulic conductivity of the
alluvial sand aquifer and saprolite aquifer about 1.7 m/day assuming an aquifer 6 m
thick. These values are higher than those derived from the constant-rate test.

The extrapolated curve intersects 0 m residual drawdown at t/t’ equal to
approximately 1.7, which suggests that storage in the saprolite aquifer was not
depleted nor did recharge take place during the test (Driscoll 1986).

4.2.2 Monitoring bores

Recovery in monitoring bores at site 00TAM21 15 m from the production bore was
monitored at regular intervals for 24 hours after cessation of pumping. Recovery
data are given as a plot of residual drawdown versus the ratio of t/t’ in Figure 4-10.

The slope of the residual drawdown curve from t/t’ 20.92 to 120.5 for deep bore
00TAM21D indicated aquifer transmissivity of 10 m²/day and therefore hydraulic
conductivity of about 1.7 m/day. These values are in close agreement with those
derived from the drawdown curve during the constant-rate test and correlate with
those determined from analysis of the residual drawdown curve of production bore
data.

Extrapolation of the residual drawdown curve for the intermediate and shallow bores
00TAM21I and 00TAM21M indicated that complete recovery would not occur,
suggesting some depletion of the alluvial sand aquifer during the test.
Figure 4-9: Residual drawdown of production bore 00TAMPB1.

Discharge rate \( (Q) = 78 \text{ m}^3/\text{day} \)
Static Waterlevel = 2.64 m (bgf)
Recovery in remaining monitoring bores was measured several times for 24 hours after pumping stopped. In all cases, minimal to no recovery occurred in the first 24 hours and so insufficient data were available for analysis.
4.3 Aquifer parameters

Parameters calculated from test pumping data for production and monitoring bores are presented in Table 4-1. However, not all plots sufficiently satisfied theoretical conditions and may not be representative of aquifer conditions. Correspondingly, estimation of aquifer parameters must be undertaken by interpreting the test results based on an understanding of testing, the bore construction and the strata intersected.

The production bore screens multiple aquifers so the water level recorded was a result of combined influences from these aquifers. In general, production bore data are less reliable than monitoring bore data due to turbulence in the production bore created by pumping. In addition, recovery data may be more accurate than data collected during pumping, as recovery data are not affected by variations in discharge rate. However, the production bore drawdown trend from the test on bore 00TAMPB1 was reasonable and may provide an estimate of aquifer parameters.

Data from most of the monitoring bores do not satisfy theoretical conditions for Jacob’s analysis (Cooper and Jacob 1946) mostly due to the large distances from the production bore. However, bores at site 00TAM21 are located 15 m from the production bore and aquifer parameters calculated using data from these bores are the most likely to be representative of the aquifers. Aquifer parameters calculated from the distance-drawdown analyses may also be reasonably representative.

Calculated transmissivity using data from the production bore and bores at site 00TAM21 ranged from 4 to 123 m²/day and hydraulic conductivity from 0.7 to 62 m/day. Of these, the higher values were probably not supported by the interpreted nature of the strata and the lower values were likely to be more representative. Correspondingly, for modelling purposes it is recommended that initial model parameters should be:

**Saprolite aquifer** – Transmissivity of 10 m²/day and hydraulic conductivity of 1.7 m/day; confined storage coefficient of $$8.5 \times 10^{-4}$$.

**Alluvial sand aquifer** – Transmissivity of 45 m²/day and hydraulic conductivity of 11 m/day; confined storage coefficient of $$4.0 \times 10^{-8}$$.

Strata considered to be an aquitard should initially be assigned significantly lower values.
Table 4-1. Tambellup 2001 test pumping - aquifer parameters

<table>
<thead>
<tr>
<th>Bore</th>
<th>Distance from production bore (m)</th>
<th>Interpreted aquifer thickness (m)</th>
<th>Drawdown after 20 days of pumping (m)</th>
<th>Calculated transmissivity (m²/day)</th>
<th>Calculated hydraulic conductivity (m/day)</th>
<th>Calculated storativity</th>
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<td>00TAMPB1</td>
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<td>16.40</td>
<td>4</td>
<td>0.7</td>
<td>1.7</td>
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</tbody>
</table>

**Deep bores:** 20 to 28 m deep, screened in saprolite, alluvial clay or pallid zone sandy clay

<table>
<thead>
<tr>
<th>Bore</th>
<th>Distance from production bore (m)</th>
<th>Interpreted aquifer thickness (m)</th>
<th>Drawdown after 20 days of pumping (m)</th>
<th>Calculated transmissivity (m²/day)</th>
<th>Calculated hydraulic conductivity (m/day)</th>
<th>Calculated storativity</th>
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<tr>
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<td>6</td>
<td>5.77</td>
<td>8</td>
<td>1.3</td>
<td>1.7</td>
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<td>8</td>
<td>n/a</td>
<td>1.3</td>
<td>n/a</td>
</tr>
</tbody>
</table>

**Intermediate bores:** 8 to 12 m deep, screened in alluvial sand

<table>
<thead>
<tr>
<th>Bore</th>
<th>Distance from production bore (m)</th>
<th>Interpreted aquifer thickness (m)</th>
<th>Drawdown after 20 days of pumping (m)</th>
<th>Calculated transmissivity (m²/day)</th>
<th>Calculated hydraulic conductivity (m/day)</th>
<th>Calculated storativity</th>
</tr>
</thead>
<tbody>
<tr>
<td>00TAM21I</td>
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<td>123</td>
<td>45</td>
<td>31</td>
</tr>
<tr>
<td>T5D/97</td>
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<td>0.45</td>
<td>39</td>
<td>n/a</td>
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</tr>
<tr>
<td>00TAM13I</td>
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<td>6</td>
<td>0.24</td>
<td>50</td>
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<td>8</td>
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<td>T12D/97</td>
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<td>1</td>
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<td>n/a</td>
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<td>4</td>
<td></td>
<td>48</td>
<td>n/a</td>
<td>12</td>
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**Shallow bores:** 2 to 6 m deep, screened in alluvial clay and sandy clay

<table>
<thead>
<tr>
<th>Bore</th>
<th>Distance from production bore (m)</th>
<th>Interpreted aquifer thickness (m)</th>
<th>Drawdown after 20 days of pumping (m)</th>
<th>Calculated transmissivity (m²/day)</th>
<th>Calculated hydraulic conductivity (m/day)</th>
<th>Calculated storativity</th>
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<tr>
<td>00TAM21M</td>
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<tr>
<td>00TAM14M</td>
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</tbody>
</table>

Values in *italics* are likely to be inaccurate and are considered unrepresentative of aquifer conditions.

n/a = values not calculated (not available).
5. Recommended operation - bore 00TAMPB1

Long-term or 180-day drawdown in the production bore was predicted for various discharge rates by extrapolating the best-fit section of drawdown curves recorded during test pumping (Figure 4-1 and Appendix). This indicated that production bore 00TAMPB1 might be capable of a long-term discharge rate of 60 m$^3$/day when pumped in isolation.

Extrapolation of the test data suggested that pumping the production bore at 60 m$^3$/day might result in a long-term operational water level of about 17 m bgl in winter and 18 m bgl in summer. These water levels were extrapolated from pumping constantly for a relatively short time and should be regarded as indicative only. Further, the predicted seasonal water levels are about 9 and 8 m, respectively, above the top of the saprolite aquifer and if this commences dewatering, drawdown is likely to increase at a substantially greater rate and the bore may be unable to sustain the recommended rate. Correspondingly, care should be taken to maintain a water level at or above about 18 m bgl as this coincides approximately with the water level during the 20-day test when drawdown began to increase at a rate that might be unsustainable.

The sustainable discharge rate may be lower than 60 m$^3$/day after prolonged dry periods or if annual recharge was lower than annual abstraction and this can only be assessed through long-term monitoring. The sustainable rate may also be lower if other production bores are drilled that mutually interfere with production bore 00TAMPB1. As a result, low flow cut-off switches should be installed in the bore.

Recommended pump depth in the bore is 25 m bgl, which is within the screened section, so a pump shroud is recommended to maintain flow past the motor for cooling purposes. Specifications of the pump (make and model) and rising main (type, length and internal diameter) must be documented so that pump performance can be assessed without having to remove the pump from the bore.

A dip tube with a minimum internal diameter of 19 mm must be fitted to the pump column in the production bore to facilitate water level monitoring. The tube must be straight and accessible from the bore headworks to the top of the pump, where it should have a short slotted interval and basal cap. A threaded plug should be present at the surface to provide a removable seal to the dip tube and prevent insect infestation. The tube can be designed to be used as an air line also, but an air line is not a suitable replacement. Nominal dip tube design is shown in Figure 5-1.
Figure 5-1: Schematic example of dip tube design and installation.
6. Requirements for dewatering

Monitoring bores in Tambellup measure either the perched watertable, regional watertable or the potentiometric surface, depending on their location and depth of installation.

Bores drilled to shallow depths (<6 m) at several sites measure what has been interpreted as a perched watertable. The perched watertable is within 1 m of the ground surface during winter and varies by up to 2 m seasonally.

Bores drilled to intermediate depths (8 to 12 m bgl) measure the regional watertable. The watertable forms the surface of a shallow aquifer containing saline groundwater and varies seasonally in elevation by as much as 1.5 m. The watertable has a primary physical impact on the soil zone and structures in and on the soil, and is likely to be causing damage to infrastructure in parts of the town. Therefore, lowering the watertable is the goal of dewatering. However, lowering the watertable in shallow aquifers directly through pumping is often difficult because of limited available drawdown. This can prevent establishment of bores with yields sufficient to produce drawdown over a large distance.

Deep bores measure a potentiometric surface, which marks the pressure of water in the deeper aquifer and reflects catchment-wide groundwater pressures. While the watertable has the primary physical impact, the potentiometric surface plays a significant role in controlling vertical movement of groundwater from shallow to deep aquifers. The potentiometric surface lies between 2.2 and 2.8 m bgl at most sites during winter. Drawdown of the potentiometric surface has benefit by aiding drainage of shallow groundwater, which can then lead to lowering of the watertable. It is difficult to quantify accurately, but the lower the potentiometric surface, relative to the watertable, the greater the potential for downward movement of shallow groundwater. It is possible to construct bores in deep aquifers that have relatively large available drawdown such that reasonably high yields may be possible that produce drawdown in both the potentiometric surface and watertable over significant areas.

The threshold watertable depth above which damage to Tambellup town infrastructure occurs is variable depending on strata at the site and on materials and methods used in construction. The Department of Agriculture found that in areas prone to salinity, the critical depth below ground to a saline watertable is 1.5 to 1.8 m (Nulsen 1981). Therefore, it is assumed for the purpose of this report that the watertable beneath Tambellup must remain below 1.8 m to prevent damage to infrastructure from rising water.

Using the highest winter groundwater levels recorded between 2000 and 2002, depth to the regional watertable in Tambellup is between 1.0 and 2.6 m. In the main residential part of town, east of the railway line, depth to the watertable is between 1.5 and 2.5 m bgl. On this basis, up to 0.8 m drawdown of the watertable may be required to protect infrastructure in Tambellup. However, annual rainfall in 2000, 2001 and 2002 was 374, 401 and 371 mm respectively, which is lower than the long-term average of 458 mm. Average or above-average annual rainfall may result in higher watertables and in greater drawdown being required to protect infrastructure in the future.
6.1 Area of influence

The area of influence on the watertable and potentiometric surface as measured in intermediate and deep bores, by pumping production bore 00TAMPB1 for 180 days at 60 m³/day can be estimated graphically by extrapolation of the test data (Figures 4-3 and 4-5). Drawdown at varying distances is calculated using the regression trend line.

Extrapolation of distance-drawdown data for intermediate monitoring bores indicates that pumping can successfully lower the watertable and that drawdown of 0.8 m or greater may occur up to about 30 m from the production bore after six months pumping. Drawdown of the watertable by 0.5 m may occur to about 150 m from the production bore and drawdown of 0.3 m may occur to about 430 m.

Extrapolation of the data for deep monitoring bores indicates that pumping can successfully lower the potentiometric surface and that drawdown of 1.0 m may be achievable to about 500 m from the production bore after six months pumping.

It is uncertain if water levels, in what is interpreted to be the perched aquifer, will respond to pumping on the basis of available data. In order to determine if the aquifer is perched or part of the regional watertable it will be necessary to measure the response to pumping of water levels in the aquifer. Monitoring of a series of shallow bores drilled to about 2 m depth set at distances of about 25, 50 and 100 m in two directions from the production bore should achieve this. If the aquifer proves to be perched, is unresponsive to groundwater pumping, and causing damage to infrastructure, then alternative methods may be required to lower the perched aquifer water levels.

6.2 Mutual interference and production bore spacing

The radius of influence of pumping decreases exponentially and more than one production bore may be required to protect infrastructure in areas where greater drawdown is required or if groundwater recharge increases in the future.

Where more than one bore is required for dewatering, calculations to estimate drawdown based on mutual interference between production bores are required for planning. These calculations can be quite complex where numerous bores are needed and in these instances, computer modelling is often used. However, for less complicated situations where perhaps only two or three bores are required, then predictions of approximate drawdown are readily achieved using graphical methods.

Using graphical methods, it is assumed that bore spacing required to achieve the target drawdown is twice the distance from a production bore at which 50% of the target drawdown would be achieved. On this basis, 100% of the target drawdown would be achieved by mutual interference from an adjacent production bore.

Extrapolation of the distance-drawdown data (Figure 4-5) suggests bore spacing required to achieve drawdown of 0.3, 0.5 and 0.8 m in the regional watertable would be about 1900, 1100 and 500 m, respectively.
The estimated distances assume a homogenous isotropic aquifer not present at Tambellup, but nonetheless, the predictions serve as useful guides for initial infrastructure planning. If higher bore discharge rates are possible, then bore spacing calculated herein may represent the worst case. Conversely, if discharge rates are lower, more bores would be required for dewatering.

6.3 Requirements for additional production bores

Drawdown of up to 0.3 m may be sufficient to provide protection to infrastructure east of the railway line given that the winter high watertable is mostly more than 1.5 m bgl. This drawdown may be achieved up to about 430 m from the current production bore which takes in most areas east of the railway line with a shallow watertable.

On the basis of 0.8 m drawdown providing ample protection to infrastructure in the entire town, then extrapolation of test data suggests the existing production bore may protect up to 30 m away. Therefore, three additional production bores may be required, pending assessment of the longer-term effect of the existing bore.

Suggested locations for production bores east of the railway line are at the intersection of Taylor Street with North Terrace and of Owen and Parker Streets. West of the railway line, a suggested location is at the intersection of Donald and Gordon Streets (Figure 6-1).

Suggested locations for production bores are approximate and may be refined on site by up to 100 m with regard to land ownership, access and distance from a power source if required for pumping.

6.4 Potential for other production bores

Potential of other sites around Tambellup for production bores is unclear due to limited detailed hydrogeological data available. However, bores 00TAM12D, 00TAM17D and 00TAM18I, drilled in the eastern part of town, were drilled to basement rocks and intersected both the alluvial sand and saprolite aquifer as did bore 00TAMPB1. On this basis there may be potential for other sites in Tambellup suitable for production bores.

Measurements taken by the Department of Agriculture in 2002 (pers. comm. M. Pridham) showed that bores drilled to basement produced airlifted yields of 22 to 138 m$^3$/day. Airlifted yields of bores drilled to depths of less than 12 m were between 1 and 10 m$^3$/day. While differences in depth of submergence during airlifting may have contributed to the difference, the data suggested higher yields can be achieved by constructing bores to basement rock.

Investigation bores should be drilled at potential sites for production bores prior to production bore drilling. Investigative drilling should be undertaken using an air-core system capable of constructing 50 mm monitoring bores through the inside of the drill string. This method facilitates direct measurements of airlift yield and salinity while drilling and gives a better understanding of aquifer potential than mud rotary drilling.

Production bores should be constructed to target only one aquifer or have the ability to isolate aquifers through packers so that more rigorous analysis of test pumping data is achievable.

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7. Conclusions

A perched aquifer with water levels within 1 m of ground surface during winter may be present in parts of Tambellup, but deeper aquifers containing saline groundwater form the most extensive aquifers below the town.

The regional watertable was measured by bores drilled to intermediate depths (8 to 12 m). These bores generally intersect an aquifer formed by alluvial sand. The regional watertable contains saline groundwater which is 1.0 to 2.5 m bgl during winter and likely to be causing damage to infrastructure in parts of town.

A deeper aquifer is formed by saprolite, which contains saline groundwater semi-confined by overlying clay and silt. This deep aquifer has a potentiometric surface which reflects catchment-wide groundwater pressures. This surface at most sites is between 2.2 and 2.8 m bgl during winter and unlikely to be directly impacting on soil and infrastructure at the surface.

The full extent of the potential perched aquifer in Tambellup is unknown and test pumping has not proven if the aquifer is perched or part of the regional watertable aquifer. Test pumping also did not show if this aquifer responded to pumping.

The production bore screens multiple aquifers, which makes determination of parameters for individual aquifers difficult. Estimates of initial aquifer parameters for use in groundwater modelling have been made from analysis of test pumping data. For the alluvial sand aquifer, transmissivity of 45 m$^2$/day, hydraulic conductivity of 11 m/day and confined storage coefficient of $4.0 \times 10^{-8}$ are recommended. For the saprolite aquifer, transmissivity of 10 m$^2$/day, hydraulic conductivity of 1.7 m/day and confined storage coefficient of $8.5 \times 10^{-4}$ are recommended.

Test pumping indicated that production bore 00TAMPB1 may be capable of a long-term discharge rate of 60 m$^3$/day. The testing has also shown that pumping may successfully lower the regional watertable and the potentiometric surface of the deeper aquifer. It is possible that greater pumping effect may be achieved in a north-west direction rather than to the south-west or south-east.

East of the railway line, winter watertable highs are between 1.5 and 2.5 m bgl and drawdown by up to 0.3 m may be required to prevent damage to infrastructure. This drawdown may be achieved up to about 430 m from production bore 00TAMPB1 after six months of pumping at 60 m$^3$/day. A 430 m radius around the current production bore takes in most areas east of the railway line with a shallow watertable.

To protect the entire town, drawdown of the watertable by 0.8 m may be required and this may occur up to about 30 m from the current production bore after six months of pumping at 60 m$^3$/day. Test pumping has indicated that drawdown in the watertable by 0.8 m may be achievable by bores spaced about 500 m apart. Three additional production bores may be needed for this.

Drawdown of the potentiometric surface by 1.0 m may be achievable up to about 500 m from the production bore after six months of pumping. This will aid in draining shallow groundwater and enhance drawdown. Drawdown required is based on watertable monitoring data from 2000 to 2002, a period with below-average rainfall. For periods of average or above-average rainfall when recharge may be higher, a greater drawdown may be required.
8. Recommendations

It is recommended that production bore 00TAMPB1 be equipped with a pump set at 25 m below ground and pumped initially at a discharge rate of 60 m$^3$/day. Predicted long-term operational water level is about 17 m below ground in winter and 18 m below ground in summer. Monitoring of bore discharge volumes, discharge rates, water levels and water salinity is required in order to provide data to assess the effect of pumping.

Monitoring of water levels in the potentially perched aquifer in Tambellup is required to assess if the aquifer is perched. To achieve this it is recommended that six shallow bores be drilled to 2 m depth at distances of about 25, 50 and 100 m in two directions from the production bore. It may be possible to drill these bores using a hand auger. Water levels in these bores should be monitored weekly once pumping commences. If water levels in the aquifer are not affected by pumping in the long-term, then it may be concluded that the aquifer is perched, in which case alternative requirements for dewatering this aquifer such as augmenting surface drainage should be investigated.

If pumping bore 00TAMPB1 proves insufficient to adequately lower the watertable in the regional watertable aquifer, then installation of further production bores should be considered. There may be a requirement for three additional production bores to cover the entire town, depending on the success of pumping bore 00TAMPB1. Suggested locations for these bores are at the intersections of Taylor Street and North Terrace, Owen and Parker Streets and Donald and Gordon Streets. These locations may be refined by up to 100 m with regard to land ownership, access, distance from a power source and strata intersected during drilling.

Production bores should be constructed to target only one aquifer or be able to isolate aquifers through packers so that more rigorous analysis of test pumping data is achievable. It is suggested that drilling and commissioning of further production bores be staged over several years depending on the assessed performance of the existing dewatering system.

Investigation bores drilled to basement rock should be located at potential sites for production bores prior to production bore drilling. Drilling should undertaken using an air-core system capable of constructing 50 mm monitoring bores through the inside of the drill string. Production bores should then be drilled using mud rotary drilling techniques at sites with the best potential for pumping.
9. References


Appendix: Test Pumping Analysis Sheet

GLOBAL GROUNDWATER

Test Pumping Analysis Sheet

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<td>Dept. of Agriculture</td>
<td>Calculations for Bore:</td>
<td>00TAMPB1</td>
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<td>Screens (mbgl):</td>
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<td>Bore Diameter (mm):</td>
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<td>Duration (hours):</td>
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<td>SWL (mbgl):</td>
<td>2.640</td>
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Recommended Bore Discharge Rate and Pump Depth Setting

Extrapolation Period: 180 Days or 259200 minutes

The 180 Day Extrapolated Drawdown (s) = 19.05 m

And the 180 Day Specific Capacity (Q/s) at the tested rate = 4.08 m$^3$/day/m

Using long-term extrapolated specific capacity, drawdown can be predicted for various discharge rates:

Long term drawdown @ 60 m$^3$/day = 15 m

If seasonal decline in aquifer water level of 0 m was allowed for, then the long-term predicted water level would be 18 m bgl.

recommended constant (24 hour) discharge rate for the bore is 60 m$^3$/day

The recommended pump inlet depth for the bore is 25 m bgl

Comments

The maximum water level recorded during the test period was approximately 20 m and therefore the behaviour of the aquifer when the water level falls below this has not been observed. Irrespective of the discharge rate recommended, the predictions are based on only short-term pumping and longer-term monitoring of water levels is required to track actual aquifer behavior. A low flow cut out switch is required to protect the pump motor should water levels fall lower than predicted. The recommended pump depth setting is within the bore screen and therefore a pump shroud is recommended for cooling purposes.
GLOBAL GROUNDWATER

Test Pumping Analysis Sheet

Job No.: 0  Pumped Bore: 06TAMPB1
Client: Dept of Agriculture  Calculations for Bore: 06TAMPB1

Screens (mbgl): 1 to 20  Bore Diameter (mm): 112

Test Start: 23-Mar-01 10:06  Bore Radius (m): 6.0061
Test End: 13-Apr-01 07:06  Discharge Rate Q (m³/day): 78

Duration (hour): 477.8  SWL (mbgl): 2.640

Recommended Bore Discharge Rate and Pump Depth Setting

Extrapolation Period: 150 Days or 219220 minutes

The 150 Day Extrapolated Drawdown (s) = 19.05 m
And the 150 Day Specific Capacity (Q/s) at the tested rate = 4.68 m³/day/m

Using long term extrapolated specific capacity, drawdown can be predicted for various discharge rates:

Long term drawdown @ 60 m³/day = 15 m

If seasonal decline in aquifer waterlevel of 0 m was allowed for, then the long term predicted waterlevel would be 18 m bgl.

recommended constant (24 hour) discharge rate for the bore is 60 m³/day

The recommended pump intake depth for the bore is 25 m bgl

Comments

The maximum waterlevel recorded during the test period was approximately 20 m and therefore the behaviour of the aquifer when the waterlevel falls below this has not been observed. Irrespective of the discharge rate recommended, the predictions are based on only short-term pumping and longer-term monitoring of water levels is required to track actual aquifer behavior. A low flow cut out switch is required to protect the pump motor should water levels fall lower than predicted. The recommended pump depth setting is within the bore screen and therefore a pump strainer is recommended for cooling purposes.